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Injury of American Eels Captured by Electrofishing and Trap-Netting

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Abstract.—We compared the incidence of internal injuries in adult American eels *Anguilla rostrata* captured by trap-netting ($N = 20$) and by 30-Hz, pulsed-DC electrofishing ($N = 18$) in the St. Lawrence River, New York. On average, the lengths and weights of fish caught by the two methods were similar. Radiographic imaging revealed that spinal damage occurred in 60% of the electroshocked American eels but only 15% of the trap-netted American eels. Bilateral filleting showed hemorrhages in 30% of the electroshocked fish but none of the trap-netted fish. Electrofishing caused significantly higher incidences of both spinal damage and hemorrhage than did trap-netting. Most electroshocked American eels had multiple spinal injuries; hemorrhages occurred only in fish with multiple sites of vertebral damage. We recommend that workers avoid the use of 30-Hz, pulsed DC to capture American eels that are intended for release; a lower frequency, such as 15 Hz, may significantly reduce injury but may also result in unacceptably low capture rates. We hypothesize that electroshocked American eels are at high risk for injury because of their large size (>90 cm) and high vertebral count (>100).

American eels *Anguilla rostrata* are found in marine and freshwater habitats along the eastern coast of North America (Scott and Crossman 1973). Subsistence and commercial fisheries for American eels and other anguillids have existed in North America and elsewhere for centuries (Tesch 1977). The New York Power Authority (NYPA) has been conducting studies on the life history, migration patterns, and behavior of American eels in the St. Lawrence River, New York, since 1997. In 2001, investigations centered on determining which collection techniques, including stow nets, hoop nets, and electrofishing, are most appropriate for downstream-migrating adults. Electrofishing was selected as a technique of interest because high catch per unit effort (CPUE) was attained in previous NYPA studies, but there was also a concern about injury to eels collected by this method. Although electrofishing is a well-established capture technique in fisheries science, many studies done during the 1990s have confirmed that electroshock may cause internal injury, particularly in large salmonids (Reynolds and Holliman 2000). We could find no published studies of electroshock-induced injury in anguillids. In this study, we compared incidence and severity of internal injury (spinal damage and hemorrhage) among American eels captured by electrofishing and trap-netting in the St. Lawrence River.

Methods

All American eels were captured at night during 10–25 August 2001 in the main channel of the St. Lawrence River between the Moses-Saunders Power Dam (Massena, New York) and Goose Neck Shoal (near Coles Creek State Park, New York), about 30 km upstream of the dam. Trap nets were deployed in or near mid-channel at depths of 2–20 m. Electrofishing was performed in shallow (<6 m depth) waters over shoals or near points in or near mid-channel.

Two types of trap nets were fished facing upstream. Hoop nets were 5 m long and 1 m in diameter, with 1.8-cm stretch mesh, two 9-m wings, and a 20-m center lead. Stow nets were 30 m long, 13 m wide, and 7 m high, with 5-cm or 1.25-cm stretch mesh and two 21-m wings. Hoop nets were lifted every 24 h and stow nets were lifted every 4–11 h. For purposes of injury comparisons with electrofishing, we made no distinction between American eels caught by hoop net or stow net.

Electrofishing was conducted with a boat-mounted, Smith-Root, Inc., type VI-A control unit powered with a 5,000-W generator. Two 33-cm, stainless-steel spheres, each suspended from a bow-mounted boom, served as anodes. Two 40-cm spheres, each suspended from one side of the boat near the stern, served as cathodes. Output

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TABLE 1.—Spinal damage and hemorrhage injuries in American eels captured by electrofishing and trap-netting in the St. Lawrence River, New York, in 2001. Severity of injury was assessed by inspection of radiographs (spinal injury) or fillets (hemorrhage) and was classified on a scale of 0 to 3 (Reynolds 1996). Final severity for each individual was determined as the rating of the worst spinal injury (0 = no damage, 1 = vertebral compression, 2 = misalignment, and 3 = fracture or separation) and the worst hemorrhage injury (0 = no hemorrhage, 1 = one or more wounds isolated in the muscle, 2 = one or more small wounds equal in width to two or fewer vertebrae, and 3 = one or more large wounds greater than two vertebrae in width).

Capture method	Number of fish	Spinal damage severity class				Hemorrhage severity class			
		0	1	2	3	0	1	2	3
Electrofishing	18	8	2	3	5	13	0	1	4
Trap-netting	20	17	1	0	2	20	0	0	0

from the control unit was 30-Hz, pulsed DC (square wave, 5–6-ms pulse width, 15–18% duty cycle) at a peak voltage of 336 V and a peak current of 4–5 A.

Captive fish were handled carefully to minimize additional injury beyond any that might have been sustained during capture. American eels in trap nets were released directly from the cod end into large holding tanks; those caught by electrofishing were dipnetted and transferred to holding tanks. Fish were anesthetized in the holding tanks with a 50-mL/L concentration of clove oil. They were then weighed, measured, and jaw-marked with numbered T-bar Floy tags, and were allowed to recover in freshwater (to assure good condition when frozen). After transfer to an onshore holding facility, the fish were euthanatized in a 500-mL/L solution of clove oil and freshwater, and were frozen straight on flat racks in a nearby freezer facility prior to shipping.

All injury analyses were conducted at the University of Alaska, Fairbanks. After being thawed, each fish was radiographed in both dorsal and lateral perspectives, then filleted on both sides. Fillets and radiographs were examined by workers who had no knowledge of the method used to capture each fish. Radiographs were evaluated to identify the location(s) of spinal injury (head-to-tail vertebral number) and the perceived severity of the spinal damage (0 = no damage, 1 = vertebral compression, 2 = misalignment, 3 = fracture or separation; Reynolds 1996) at each site of injury. The final severity rating for each fish was the worst vertebral injury found. Filleted fish were inspected for the worst hemorrhage based on perceived severity (0 = no hemorrhage, 1 = one or more wounds isolated in the muscle, 2 = one or more small wounds equal in width to two or fewer vertebrae, 3 = one or more large wounds greater in width than two vertebrae; Reynolds 1996).

Differences in mean length and weight between capture methods were tested for significance with a two-tailed *t*-test. Incidence of injury for each electrofishing or trap-net sample was expressed as the percentage of fish with a hemorrhage or spinal injury, regardless of severity. Incidences of hemorrhage and spinal damage were analyzed and reported separately (Schill and Elle 2000). Fisher's exact test (Sokal and Rohlf 1981) was used to evaluate the null hypothesis of no association between capture method and incidence of injury. Severity and location of spinal injuries were compared between electrofishing and trap-net samples by use of the perceived severity classification and vertebral counts, respectively.

Results

Of the 38 American eels analyzed for injury, 18 were captured by electrofishing and 20 were captured in trap nets. Eels caught by electrofishing averaged 917 mm in length (SD = 81 mm) and 1,633 g in weight (SD = 533 g); those caught by trap-netting averaged 956 mm in length (SD = 61 mm) and 1,894 g in weight (SD = 446 g). Neither average lengths ($t = 1.673$, $P = 0.103$) nor average weights ($t = 1.612$, $P = 0.109$) differed significantly between trap-netted and electrofished American eels.

None of the captured American eels had external injuries. Of the 20 trap-netted eels, 3 (15%) had spinal damage but none had hemorrhages (Table 1). One trap-netted eel had a single, class-1 vertebral injury (vertebrae 27–28), one had a single, class-3 injury (vertebrae 31–32), and one had multiple class-1 injuries (vertebrae 24 and 26) and class-3 injuries (vertebrae 17–18, 25, and 28–29). Spinal damage in these fish was probably caused by capture and handling, because the injuries were neither old (healed, indicated by calcium deposition on a radiograph) nor congenital (malformed,

TABLE 2.—Number and location of all spinal injuries, irrespective of perceived severity, in American eels captured by electrofishing and trap-netting in the St. Lawrence River, New York, in 2001. The number of injuries exceeds the number of fish because some fish had multiple injuries.

Capture method	Injured fish (*N*)	Vertebral number (head-to-tail)					
		1–19	20–39	40–59	60–79	80–99	100+
Electrofishing	10	5	17	11	3	0	0
Trap-netting	3	1	6	0	0	0	0

indicated by misshapen vertebrae or extra spines attached to vertebrae).

Of the 18 American eels captured with 30-Hz, pulsed-DC electrofishing, 10 (60%) sustained spinal damage and 5 (30%) had hemorrhages (Table 1). None of the vertebral injuries were old or congenital. The incidence of both types of injury was significantly higher among electroshocked eels than among trap-netted eels (spinal damage $P < 0.016$, hemorrhage $P < 0.017$). Spinal damage was found at all levels of severity, but especially classes 2 and 3 (Table 1). Of the five eels that suffered hemorrhages, four had wounds rated at severity class 3, and one had injury rated at class 2. Three of the electroshocked eels with vertebral injury had single-site damage; the remaining seven had 3–6 injuries each. Most spinal damage occurred in the region of one-third of the body length from the head (vertebrae 20–39; Table 2). Hemorrhages occurred only in eels with multiple sites of spinal damage.

Discussion

This is the first published study of electroshock-induced injury in anguillids. Injury rate was high among American eels caught by electrofishing: 60% had spinal damage and 30% had hemorrhages. Injuries were apparently severe (mostly classes 2 and 3). Although some injuries in the electrofished American eels may have been due to handling, as indicated by the incidence of injuries in trap-netted eels, most of the injuries were caused by electroshock. High power (336 V × 4–5 A = 1,344–1,680 W) is necessary to stun or immobilize eels in order to catch them efficiently (W. Klock, Beak Consultants, Inc., personal communication). However, the immobilization response is often associated with tetany, a severe muscular contraction, and probably increases the risk of injury (Reynolds and Holliman 2000).

Spinal injuries tended to occur at about one-third of the body length from the head; this is the area of greatest body girth (W. Klock, personal communication) and coincides with the site of greatest force during muscle contraction. We do not know what effect these injuries would have had on the health and survival of the fish if they had been released. However, the incidence and severity of the injuries would be unacceptable in cases where fish are marked and released for possible recapture.

Among electrical waveforms, AC is generally recognized as most injurious to fishes, continuous DC least injurious, and pulsed DC as intermediate in effect, depending on the pulsed-DC parameters and fish species involved. Pulsed DC is most commonly used at 60 Hz, a pulse frequency repeatedly shown to produce injury rates of 50% or more in adult salmonids (Reynolds and Holliman 2000). Pulse frequency is a key factor determining the risk of injury to fish caught by electrofishing (Reynolds 1996). Fish size is also an important factor; the injury risk increases with increasing size. Frequencies much lower than 60 Hz (e.g., 20–30 Hz) are likely to reduce injury rates among many electroshocked fishes, including smaller salmonids, but the 30-Hz frequency was obviously not low enough to avoid high injury rates in the American eels we studied. We recommend that electrofishers avoid the use of 30-Hz, pulsed DC to capture adult eels. Further reduction of pulse frequency, such as to 15 Hz, may significantly reduce injury rates but may also reduce CPUE to inefficient levels.

We hypothesize that, for a given pulse frequency and fish size, the underlying risk factor for injury is vertebral count (v). Strong-swimming, body-undulating fishes like anguillids ($v = 103$–119; Scott and Crossman 1973) and salmonids ($v = 56$–71) have higher vertebral counts associated with supple spines for maximum thrust. Spines with higher vertebral counts are less likely to withstand the force of severe muscle contraction caused by electroshock. Weak-swimming, tail-thrusting fishes like centrarchids ($v = 22$–33) have lower vertebral counts associated with robust spines that are resistant to electroshock-induced muscle contraction. We are currently working on additional experiments that will confirm or reject this hypothesis.

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